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An evaluation of FOMES ANNOSUS in YOSEMITE NATIONAL PARK

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IN YOSEMITE NATIONAL PARK

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INTRODUCTION

THE PROBLEM

Scattered dying conifers and hazardous tree incidents have been common for the last several years in Yosemite Valley of Yosemite National Park. In 1967, D.R. Miller of Region 5 Forest Service and R.V. Bega of the Pacific Southwest Forest and Range Experiment Station diagnosed Fomes annosus as the causal agent responsible for some of the tree mortality and failure. In 1971, a group of plant pathologists attending a hazardous tree conference in Yosemite Valley again diagnosed tree death and failure in several developed sites as being caused by F. annosus. The Park Superintendent, upon receiving this report, requested that the Forest Service conduct a biological evaluation of the F. annosus problem in the developed sites of Yosemite Valley. The request resulted in the formation of a cooperative study project involving the University of California, the National Park Service, and the U.S. Forest Service. The goal of this project was to develop the information needed to make a sound biological evaluation. The specific objectives were:

- a) to determine the number, sizes and locations of F. annosus infection centers within the developed sites in Yosemite Valley.
- b) to estimate the rate of spread and mortality in infection centers and the resulting vegetation changes occurring within these centers.
- c) to estimate the hazards the infected trees posed to Park visitors.
- d) to develop management options aimed at reducing stand damage and hazard.

HISTORY OF YOSEMITE VALLEY STAND

Early photographs indicate that Yosemite was covered mainly by meadows and open oak woodlands, with conifers scattered throughout at low densities. F. annosus could not have been prevalent under such conditions. As a result of fire control, grazing, and meadow drainage, dense stands of ponderosa pine and incense-cedar developed over much of the Valley floor, gradually overtopping and shading out much of the oaks. Most of the campsites, cabins, and concessionaire installations are in these pine cedar stands.

The formation of these dense stands and their subsequent development created conditions favoring the initiation and spread of two types of root diseases common to Yosemite Valley.

- a) The cutting of numerous pines for beetle control and in the development and maintenance of recreation sites created the infection courts needed for the initial introduction of F. annosus into the stands.
- b) The dense pine-cedar stands with frequent root to root contacts provided ideal conditions for tree to tree spread of F. annosus after its initial introduction.
- c) Oaks shaded out by conifers became weakened and heavily infested with Armillaria mellea. These infected oaks acted as food bases from whence this root pathogen could spread out into the surrounding pine-cedar stand.

Before root diseases can kill a tree, the diseased tree usually is attacked and killed by bark beetles. This results in many trees that die from a root disease-bark beetle complex being reported as insect killed only, and the root disease, which is basic to the whole problem, goes undetected for years. Also, since bark beetles bred in diseased trees can and do attack uninfected trees, the total mortality resulting from a root disease center may be considerably greater and cover a larger area than that due solely to root infection. This interaction between the root diseases and insects complicates studies of spread within centers.

TECHNICAL INFORMATION

THE CAUSAL AGENT

Fomes annosus, the cause of annosus root rot, is a Basidiomycetous fungus, closely related to the common wood decay fungi. It attacks a wide range of woody plants, causing both a decay of wood and a killing of sapwood and cambium.

The fungus spreads overland by spores from conks that are usually produced in decayed stumps, under the bark of dead trees, or under the duff at the root collar. These spores drift through the air and, upon landing on freshly cut pine stump surfaces or wounds in a live tree, they germinate and colonize this new habitat. Once established in a stump or tree, the fungus grows through its roots until it contacts the roots of adjacent trees. It then invades these new roots and grows through the new root system. In this way it passes from stumps or dead trees to the roots of live trees and thence onto other live trees in an enlarging circle on center. These

centers usually continue to enlarge until they reach barriers such as openings or groups of nonsusceptible plants.

Evidence from southern pines suggests that spores of F. annosus can filter down through the soil to infect roots of live trees and that insects may carry the fungus from tree to tree. We have no data to support spread by these means in the west, but circumstantial evidence suggests that infection of live trees by spores may be more common than hitherto suspected.

F. annosus may remain alive in old infected roots or stumps for many years. Young conifers established within such centers often die shortly after their roots contact old infected roots in the soil.

HOST TREES ATTACKED

F. annosus attacks most conifers. Resinous conifers, especially pines, are often killed quickly by cambial girdling before appreciable root decay occurs, but extensive decay can on occasion precede the death of a pine. Coniferous species with non-resinous wood, such as true fir or incense-cedar, usually decay to a much greater extent before they die. The infection centers in Yosemite Valley contain resinous (ponderosa pine) and non-resinous species (incense-cedar). Hardwoods are usually less liable to damage from this pathogen and may remain in or become established in centers in which most conifers have been killed.

STAND FACTORS

Because centers enlarge by root to root spread, the disease is most damaging in dense stands of susceptible trees where root contacts are frequent. Sparse stands or stands of mixed susceptible and resistant trees are less subject to extensive damage. Stand age and tree size may also be important, since roots of large trees extend from greater distances and this provide opportunities for farther spread between trees.

LOCATION AND NUMBER OF FOMES ANNOSUS CENTERS

In 1971, mortality centers were located from aerial photographs, vegetation maps, annual forest reports, and direct examination of all developed sites for current mortality, declining trees, or clusters of stumps which might indicate F. annosus centers. These mortality centers were confirmed as F. annosus centers by finding sporophores in stumps or by isolating the fungus from stumps, dead trees, or declining trees. Mortality centers were not included in this study unless positive identification of F. annosus was made.

The determination of the exact number of F. annosus centers in the developed sites of Yosemite Valley is complicated by several factors.

- a. F. annosus may be present but difficult to isolate. If after two series of isolations F. annosus could not be isolated and identified the mortality center was not included.
- b. Centers without current mortality may not have been detected.
- c. Centers in early stages of development prior to tree mortality are difficult to detect.
- d. When two or more adjacent centers emerge it is difficult or impossible to determine the number of centers involved.

For these reasons, confirmed centers were classified into the following four types.

- a. Compact single centers judged to involve a single spreading infection.
- b. Diffuse single centers with peculiar spread patterns often involving other pests such as A. mellea or bark beetles.
- c. Multiple centers that clearly involve two or more separate infection centers that overlap to the degree that the number and configuration of the individual infections cannot be determined.
- d. Unclassified centers for which no data have been taken beyond initial F. annosus conformation.

The number of centers in these categories are shown in Table 1. Developed recreation sites contained 105 confirmed centers, of which four were multiple centers representing at least 16-21 separate loci of infection. Since some of the 20 diffuse centers probably involve more than one locus of infection, the total number of confirmed individual centers of infection within developed sites exceed 120. Outside of the developed sites, 56 centers were identified from roadside and cliff-top observations and from aerial photos. Since the survey of the undeveloped areas was less thorough, the total number of infection centers in these areas is probably much larger.

TABLE 1. Numbers of F. annosus centers by type and location.

SITE	NO. OF COMPACT SINGLE CENTERS	NO. OF DIFFUSE SINGLE CENTERS	NO. OF MULTIPLE CENTERS	NO. OF UNCLASSIFIED CENTERS	TOTALS
Camp 4	0	0	0	1	1
Camp 9	0	0	0	-	0
Camp 6	6	3	0	-	9
Camp 7	7	0	1	2	10
Camp 11	5	6	0	-	11
Camp 12	4	0	0	2	6
Camp 14	4	4	0	2	10
Camp 15	6	0	0	1	7
Camp 16	2	0	0	-	2
Camp 19	1	0	0	1	2
Ahwahnee	4	1	0	4	9
Curry Village	5	0	0	2	7
Yellow Pine	2	5	1	2	10
Lodge Area	7	3	2	2	14
Cathedral P. A.	2	0	0	-	2
Yosemite Village	1	0	0	2	3
Devil's Elbow	2	0	0	0	2
Undeveloped Areas	-	-	-	56	56
TOTALS	58	22	4	77	161

Data collected by Parmeter and Felix indicate that the number of centers will continue to increase within the next few years as incipient centers become recognizable. Recent treatment of stumps hopefully will slow down the rate of center initiation.

Rates of spread of F. annosus outward from an infection center were calculated by Parmeter and Felix. They concluded that rates of 4 feet or more per year are encountered but that 2 to 3 feet per year appears to be the best estimate for rates of spread.

EXTENT OF TREE MORTALITY

The determination of the exact number of trees killed by F. annosus is complicated by the loss of older stumps and dead trees and the additional insect killed trees associated with F. annosus mortality centers. Because some trees were wind-thrown and others have been cut flush with the ground and their stumps buried, it is often impossible to identify all of the trees that have been lost in a center. Where old vegetation maps were available we usually found that physical evidence of some past kills was missing and that mortality was therefore underestimated.

It was not feasible to check each tree or stump for F. annosus and since bark beetles are known to breed in diseased trees and attack nearby uninfected trees, some mortality may be an indirect rather than direct result of F. annosus. For this reason mortality is considered to be the result of a F. annosus-bark beetle complex. The number of undetected deaths may approximate the number of deaths from other agents. The total mortality figures are therefore likely to be a reasonable reflection of mortality directly or indirectly associated with annosus root disease.

Not all plots have been analysed but in the original 69 plots mapped in 1971, 856 trees had died. By 1976, an additional 367 trees died or were removed because of advanced symptoms of root decay. Between 1971 and 1976, an additional 15 centers were mapped, with a total mortality of 184 trees. Thus the recorded mortality on mapped plots was 1407 trees. Since only about half of the confirmed centers in the Valley have been mapped, and since failure to detect much of the past mortality leads to underestimation, it is likely that the total mortality associated with F. annosus centers exceeds 3000 trees.

The current annual death rate of 80-100 trees per year is expected to increase as the numerous small centers enlarge. Losses over the next 10 years were estimated (Table 2) by determining the number of trees within 20 ft. of dead or declining trees within centers.

TABLE 2. Past mortality to 1975 and mortality predicted to 1985 at various developed sites.

SITE	NO. DEAD TO 1975	EST. NO. ADDITIONAL DEATHS IN NEXT 10 YEARS
Camp Curry	53	65
Ahwahnee	33	57
Lodge Area	302	311
Camp 6	87	86
Camp 7	41	58
Camp 11	76	124
Camp 12	33	34
Camp 14	43	24
Camp 15	160	116
Camps 16 & 19	19	15
Yellow Pine	172	254
Miscellaneous	83	129
TOTALS	1,102	1,263

Mortality has not occurred uniformly in all centers each year. Within limits, small centers tend to have lesser rates of mortality. This should be expected since a smaller center with a smaller circumference has fewer trees to be exposed to infection on the periphery.

This area is based on a conservative estimate of the rate of spread of 2 feet per year. An estimated 1,263 trees will die in the identified centers within the next ten years. This averages about 126 trees per year, a higher rate than recorded for the past 3 years.

DISCUSSION

VEGETATION CHANGES

Because pines and incense-cedars dominate Valley stands in which F. annosus occurs, most large centers are very nearly cleared. A few pines and cedars have survived, but these will probably die within a few years. Since F. annosus remains viable in old roots for many years, reforestation of centers with susceptible species is unlikely for several decades. If ground cover is to be maintained, tolerant or nonsusceptible species must be used.

F. annosus has a wide host range and attacks both hardwoods and conifers; however, hardwoods are generally more tolerant of infection than conifers. Present evidence, while yet incomplete, indicates that some hardwood tree species native to Yosemite Valley -- or presently established there -- are tolerant and will survive in F. annosus infection centers. Black oak appears to be highly tolerant or resistant. Nineteen of 122 black oaks have died in mortality centers but there is no evidence that F. annosus was involved. F. annosus has yet to be confirmed in a black oak and there are several centers where F. annosus has failed to spread into oak stands. The remaining promising species -- live oak, maple, cottonwood, and bay -- are rare in the centers, and there is insufficient data to estimate susceptibility and survival. Further monitoring of mortality centers may provide additional data, but test plantings of various species will be needed to provide a firm basis for planning if reforestation of mortality centers is contemplated.

TREE FAILURE AND HAZARD

Trees infected by F. annosus are subject to root and butt failure and hence, can be hazardous to life and property. Pines usually are killed by F. annosus before their root systems are extensively decayed; however, an occasional pine has been windthrown with advanced root decay before being killed. Since no studies have been made in pine relating root deterioration to crown symptoms, infected pines should be considered to have a high probability of failure when they exhibit advanced crown symptoms (shortened yellow needles with 1-year's needle retention). Non-resinous conifers such as firs and cedars, and probably Douglas-firs, usually sustain extensive decay of root and butts before they die and hence are liable to fail while still living. Recent studies with incense-cedar indicate that there is a good correlation between crown symptoms and the amount of root decay.

This information is being used to develop a hazard guide for incense-cedar. All dead trees have a high probability of failure, since decay proceeds rapidly after the tree dies.

A second form of tree failure and hazard is associated with F. annosus centers. When dense stands are opened up by root disease centers, protection of surrounding trees from wind is reduced. Therefore trees at the periphery of or within opened centers are liable to be uprooted or break during severe storms. Since 1971, 30 trees have uprooted and 47 trees have broken within and around mapped centers. The windthrow figure would undoubtedly be higher if the hazardous tree removal program had not eliminated many trees which had a high probability of failure. Tree failure data collected since 1971 indicate that any large conifer in or at the periphery of a F. annosus center is liable to fail. Most failures have occurred during winter storms during the off-season.

A few exceptionally-hazardous sites should have special mention:

The Yosemite Lodge area contains many F. annosus centers in stands of large trees spaced so that most buildings are within range of potential tree failures. This includes most dwellings, the cafeteria, and the lodge. Because of winter use when the probability of failure is the highest, the likelihood of fatal or damaging accidents is high.

Camps 6 and 25 have several centers of large trees so spaced that most buildings or tents are potential targets. Because of its non-winter use, these camps are less hazardous than the lodge.

The Muir-Tree walk-in campground has large centers throughout. Little hazard reduction cutting has been done here. As a result dead snags, declining trees, and probably butt-rotted firs are numerous. The likelihood of tree failure and accident are high.

Curry Village has mortality centers in the cabin area and the employees' tent area. In addition the entire Curry Village is in a belt of heavy A. mellea infestation. Because of heavy use in summer and moderate winter use, the accident potential is high.

Ahwahnee Cabins east of the hotel are within range of trees in a large mortality center.

RECOMMENDATIONS

F. annosus root disease, active in over 100 mortality centers, is widely distributed in the developed recreation sites of Yosemite Valley. To date approximately 1,400 trees have died in these centers and 1,200 more are expected to die within the next ten years. The problem already severely affecting many recreation sites is expected to worsen as the existing centers enlarge and as new centers are found.

The data indicate that most conifers in developed sites will ultimately be lost directly or indirectly to annosus root disease, perhaps in as little as 30 to 40 years. This will result in the loss of the forest cover or at best a cover of sparsely scattered hardwoods. The camping experience will decline as the forest cover is lost, and the area suitable for camping will decrease as the campgrounds are denuded.

The probability of tree failure and hazard has increased in and around the mortality centers in developed sites. This is the result of the root and butt decay and opening of the stand to windthrow. This hazard problem is expected to increase as the affected area and number of trees increases.

RECOMMENDATIONS

The control options which can be recommended are limited in number and are either preventative or indirect in nature. Some methods of hazard reduction are also needed. The available controls are as follows.

Prevention. Prevention of center initiation is highly desirable. Since infection centers are known to start with the infection of freshly-cut conifer stumps and borax treatment of the stump surfaces will prevent infection from occurring, it is recommended that all freshly-cut conifer stump surfaces be treated with dry powdered borax as indicated on the pesticide labeling. Circumstantial evidence indicates that some centers originate at suppressed trees. For this reason uprooting and removal of suppressed trees might reduce center initiation. The removal of suppressed trees would also increase the resistance of the stand to bark beetle attack.

Indirect Control. All direct control procedures for annosus root disease are costly and should be considered experimental; therefore, the only options are indirect methods of avoiding, alleviating, learning to live with, or ignoring the problem. The data indicate

preservation of present stands and stand type in many areas of the Valley is not possible and that there will be a gradual conversion to a meadow, open woodlands type of cover. The options open are to allow this conversion to occur naturally as the root disease progresses, or to hasten the conversion by thinning to release hardwoods currently in the stand, planting selected hardwoods in the present openings, clearing some pine stands or portions of pine stands and planting selected hardwoods, and/or combinations of the above. The particular option(s) chosen depends upon the Park Service's plans and objectives.

Hazard Control. Because of the large increase in tree failure and hazard resulting from annosus root disease, hazard control must be a major concern in managing the affected recreation site. There are two basic approaches to hazard control or reduction: (1) to remove the target of the hazardous trees, or (2) to remove the hazardous trees.

The first option of removing the target by closing a portion or all of a recreation site would be most appealing for those sites with small capital investments and with large or numerous root disease centers and many hazardous trees. In such areas control by hazard tree removal may so denude the area that its appeal as a recreation site is lost.

In those areas where recreation use will continue, the prompt removal of all identifiable hazardous trees is essential. Removal of declining trees will reduce the hazard from uprooting and will also increase stand resistance to beetle attack. A guide to determining the probability of failure in incense-cedar in Yosemite Valley is being prepared jointly by the Park Service, the University of California, and the Forest Service. The removal of declining trees to reduce hazard from uprooting will further open the stand and increase the probability of failure by stem breakage or windthrow, but at this time there does not appear to be any feasible method of reducing these types of failure resulting from high winds and stand openings.

The effects of this root disease on the developed sites in Yosemite Valley are so severe that they must be considered in the development of future plans for the Valley. These plans must be realistically based on future projections and on available options for disease and hazard control. After the management objectives and plans have been determined, the particular control option(s) can be chosen.